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Silvical Characteristics of Red Spruce

(Picea rubens)

by Arthur C. Hart

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Preface

MUCH of the silvical information on our forest trees is widely scattered and sometimes difficult to find. To make this material more readily available, the Forest Service is assembling information on the silvical characteristics of all the important native forest tree species of the United States. It is expected that this information will be published as a comprehensive silvics manual.

This report presents the silvical characteristics of one species. It contains the essential information that will appear in the general manual but has been written with particular reference to the species in the Northeast. Similar reports on other species are being prepared by this Experiment Station, and by several of the other regional forest experiment stations.

Silvical Characteristics of **Red Spruce**

by Arthur C. Hart

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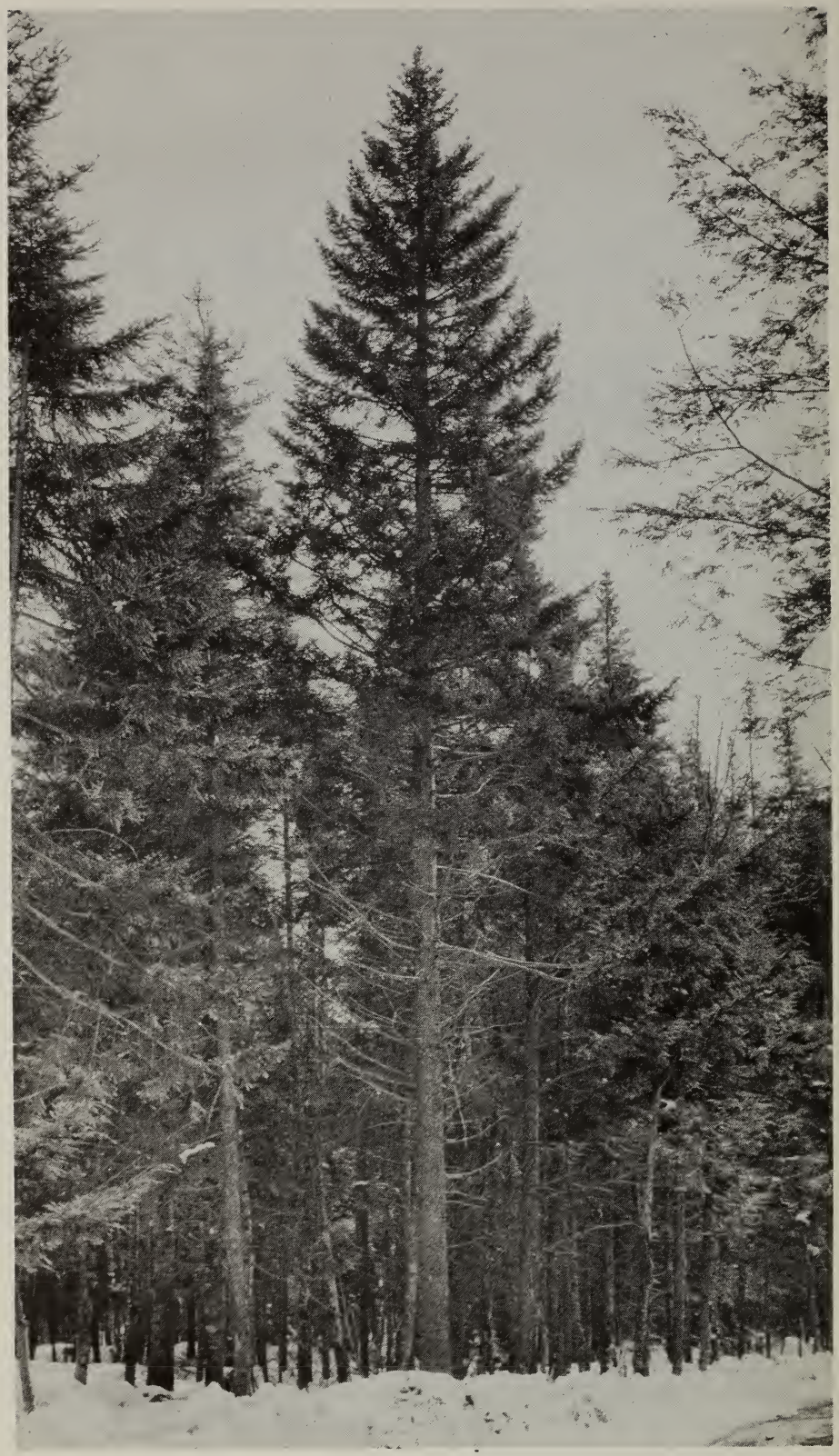
About the Author . . .

ARTHUR C. HART, *research forester, has spent most of his professional career in the spruce-fir region of the Northeast. After taking his Bachelor's degree in forestry at the University of Connecticut in 1936 and his Master's at the Yale School of Forestry in 1938, he joined the Northeastern Forest Experiment Station and did research work at Alfred, Maine, and Gale River Experimental Forest at Bethlehem, N.H. He left Federal service in 1941 to become manager for the Great Mt. Forest at Norfolk, Conn., then served as senior forester with the Exploration Division of the Rubber Development Corporation in Brazil and later with the Corps of Engineers at the American Cinchona Plantation in Costa Rica. Hart returned to the Northeastern Station in 1946, and since then has been engaged in research in the spruce-fir type at the Gale River Forest and for the past 10 years at the Station's research center at Bangor, Maine.*



MAINE EXTENSION SERVICE PHOTO

The Number One Spruce

RED SPRUCE (*Picea rubens* Sarg.) is not only the most important of the spruces; it is also one of the most important of all the conifers in northeastern North America. It is a tree of many uses. The paper industry relies heavily on it for pulpwood; in the variety of its other uses it rivals white pine.

The range of red spruce extends from Nova Scotia to Maine and southern Quebec, south to eastern New York, northeastern Pennsylvania, and northern New Jersey (fig. 1). It also occurs in the Appalachian Mountains of western Virginia, western Maryland, West Virginia, western North Carolina, and eastern Tennessee *(14, 20, 27)*. Isolated stands are found in Canada as far west as Algonquin Park and Haliburton County, Ontario *(13, 16)*.

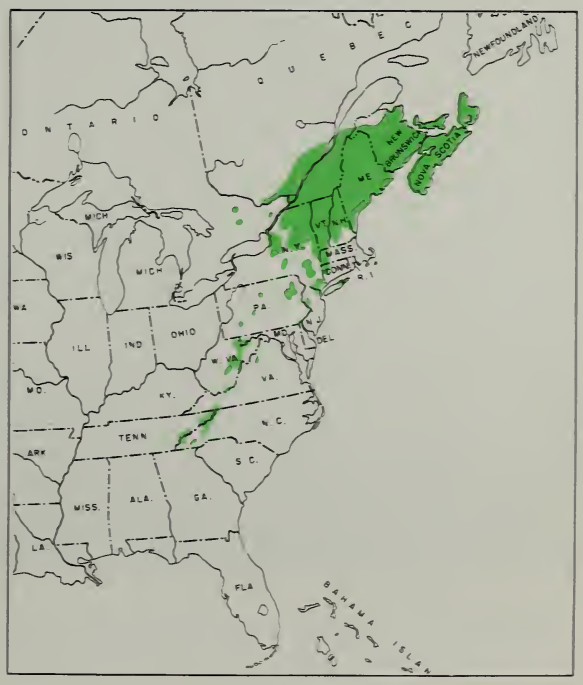


Figure 1.--*The natural range of red spruce.*

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Habitat Conditions

CLIMATIC

Red spruce grows best in a cool, moist climate. The average annual temperature over its range varies from 40° to 55° F. The average temperature for January varies from 10° to 35°; for July from 65° to 70°. The average maximum temperature for its range is 90° to 95°; the average minimum is 0° to -30°. The highest temperature on record within its range is 100° and the lowest is -40°. The frost-free period varies from 100 to 180 days and average annual precipitation from 35 to 80 inches *(35)*.

Red spruce attains its best development in the higher southern Appalachian Mountains (fig. 2) where the atmosphere is more humid and the rainfall heavier during the growing season than in other parts of its range *(19)*.

SOILS

The soils on which red spruce grows belong mainly to the broad podsol and podsolic groups and have a pH of 4.0 to 5.5 *(42)*. The tree reaches its best development on the well-drained, deep, sandy loams of mountain slopes and benches *(19)*; but it will grow on many different types of soils if abundant moisture is available *(27)*. At higher elevations in the mountains it often grows on organic soils overlying rock, where there is little or no mineral soil.

In northern New England it occurs predominantly on shallow till soils, averaging about 18 inches to a compact layer.[1] It will grow on many sites unfavorable for other species such as steep rocky slopes, thin soils and wet bottomlands. On poorly drained areas the lack of aeration in the soil limits its growth. However, the tree occurs most commonly where conditions are not ideal for its own growth but are even less favorable for its competitors *(27)*.

PHYSIOGRAPHIC

In the northern part of its range, red spruce grows from near sea level to about 4,500 feet *(27, 34)*. In the southern Appalachians, it is confined to slopes and mountain tops above 3,500 feet in West Virginia and above 4,500 feet

[1] McLintock, T.F. Physical properties of the soils of the spruce-fir region of Maine and their relation to the site index of red spruce. Unpublished thesis, Yale University, 1957.

Figure 2.--*A virgin stand of red spruce on the Monongahela National Forest in West Virginia.*

in Tennessee and North Carolina *(19)*. In the southern part of its range, the tree decreases in size and numbers as the altitude increases, giving way at the highest elevations to nearly pure stands of Fraser fir *(19, 28)*.

BIOTIC

Red spruce is a major component of six forest cover types recognized by the Society of American Foresters, and a minor component of eight *(34)*. The cover types of which it is a major component are:

Type 30--Red spruce-yellow birch
Type 31--Red spruce-sugar maple-beech
Type 32--Red spruce
Type 33--Red spruce-balsam fir (fig. 3)
Type 34--Red spruce-Fraser fir
Type 35--Paper birch-red spruce-balsam fir

Red spruce frequently occurs in pure or nearly pure stands (Type 32). Three variants of the spruce type are commonly recognized in the Northeast: old-field spruce, spruce flat, and spruce slope. Red spruce also occurs in the north mixed with the following tree species:

Balsam fir	*Abies balsamea*
White spruce	*Picea glauca*
Paper birch	*Betula papyrifera*
Yellow birch	*B. alleghaniensis*
Sugar maple	*Acer saccharum*
Red maple	*A. rubrum*
Beech	*Fagus grandifolia*
Eastern hemlock	*Tsuga canadensis*
White ash	*Fraxinus americana*
Eastern white pine	*Pinus strobus*
Northern white-cedar	*Thuja occidentalis*
Quaking aspen	*Populus tremuloides*
Bigtooth aspen	*P. grandidentata*

In the south, Fraser fir (*Abies fraseri*) and yellow buckeye (*Aesculus octandra*) are additional associates.

Shrubs and some of the more common herbs associated with red spruce include the following:

Shrubs

Witch hobble	*Viburnum alnifolium*
Mountain maple	*Acer spicatum*
Striped maple	*A. pennsylvanicum*
Mountain ash	*Sorbus americana & S. decora*
Beaked hazelnut	*Corylus cornuta*

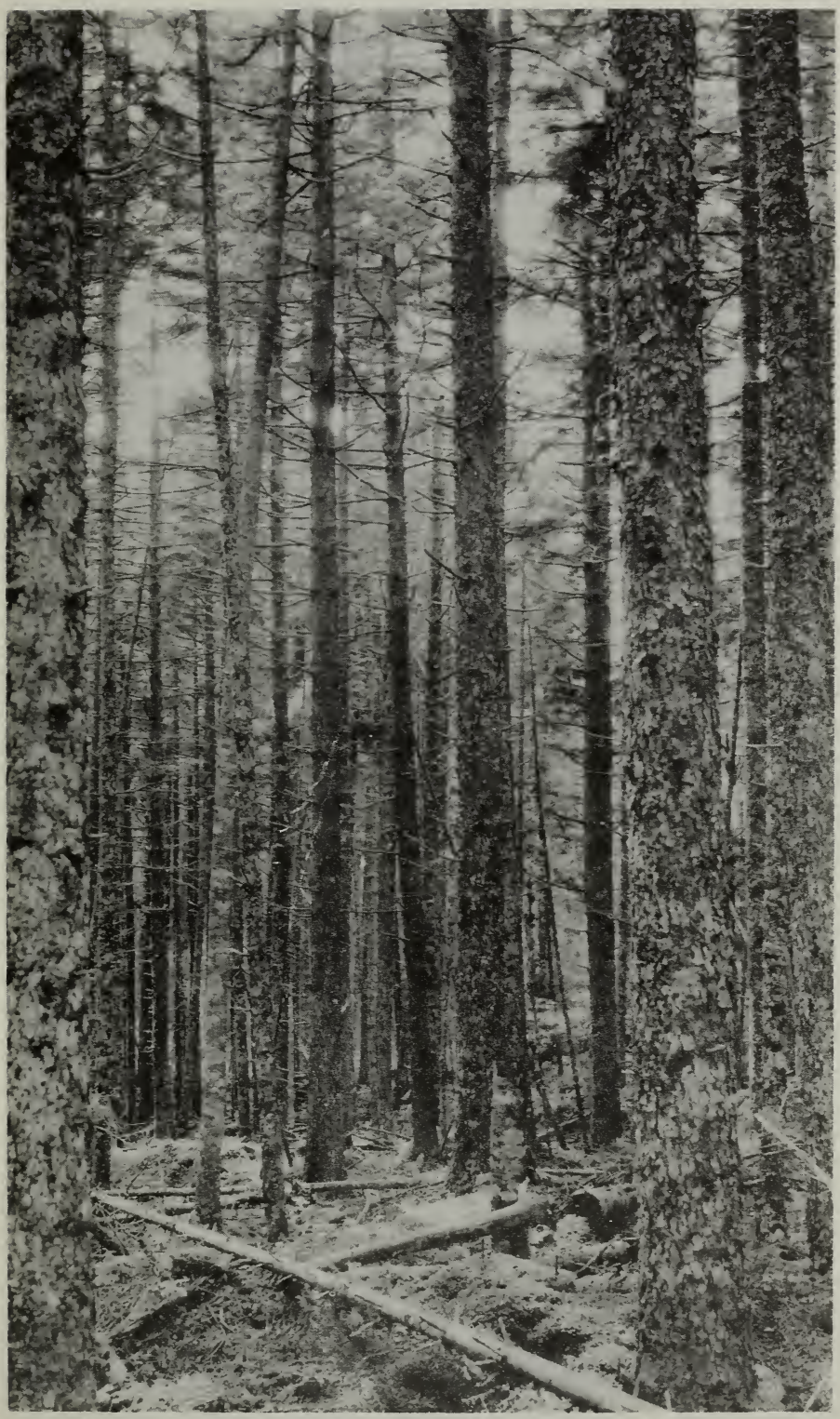

Figure 3.--*A spruce-fir stand in northern New England.*

Hazel alder	*Alnus serrulata*
Speckled alder	*A. rugosa*
Red-osier dogwood	*Cornus stolonifera*
Low-bush blueberry	*Vaccinium angustifolium*
Red raspberry	*Rubus idaeus*

Herbs

Wood sorrel	*Oxalis acetosella*
Bunchberry	*Cornus canadensis*
Canada mayflower	*Maianthenum canadense*
Clintonia	*Clintonia borealis*
Golden thread	*Coptis trifolia*
Golden rod	*Solidago macrophylla*
Star flower	*Trientalis americana*
Wild sarsaparilla	*Aralia nudicaulis*
Violet	*Viola incognita*

Mosses associated with red spruce include species of *Hylocomium, Hypnum, Dicranum,* and *Polytrichum.*

Certain mosses, herbs and shrubs found in association with red spruce indicate forest site quality *(15, 38, 39, 41)*. The three main associations, *Hylocomium-Oxalis, Oxalis-Cornus,* and *Viburnum-Oxalis,* respectively, indicate increasing site productivity along with an increasing proportion of hardwoods. The *Oxalis-Cornus* association is considered to indicate the best growing conditions for red spruce *(15)*. On these sites the soil is rich enough for the spruce, yet not sufficiently fertile to enable the tolerant hardwoods to offer serious competition.

Red spruce provides food and cover for various animals and birds. The spruce grouse (*Canachites canadensis*) feeds on the buds and foliage; red squirrels (*Sciurus hudsonicus*) eat both the buds and seeds; varying hares (*Lepus americanus*) browse twigs and foliage; and porcupines (*Erethizon dorsatum*) feed upon the bark. Red spruce seeds make up 25 to 50 percent of the diet of white-winged crossbills (*Loxia leucoptera leucoptera) (21)*.

Life History

SEEDING HABITS

Flowering and Fruiting

Male and female flowers are borne separately on twigs of the previous year's growth of the same tree. The pendant male flowers are bright red; female flowers are erect and bright green tinged with purple. Flower buds open in late April or early May somewhat before the vegetative buds.

The fruit is an ovoid $1\frac{1}{4}$- to 2-inch-long drooping cone having smooth, thin, rounded scales *(14)*; it matures the first fall from about September 15 to October 1.

Seed Production

Red spruce cone production may begin as early as 15 years in very open stands, but good production usually does not begin until after 30 years of age *(27)*. Dense stands of second-growth spruce may produce cones at 35 years of age and usually produce full crops after 45 years *(27)*. Red spruce trees under 5 inches d.b.h. seldom bear cones *(17)* but, once in production, continue to bear seed to an advanced age.

Good seed crops occur every 3 to 8 years, with light crops during intervening years. A bushel of cones yields 17 to 24 ounces of clean seed. The number of seeds per pound ranges from 100,000 to 289,000, with an average of 139,200. Although fairly good germination of red spruce seed is obtained without pretreatment, some of the seeds commonly exhibit temporary dormancy. Therefore, stratification in moist sand at 41°F. for 30 to 45 days before sowing is recommended *(36)*.

Seed Dissemination

Seedfall begins soon after the cones ripen in October and continues until March. Most of the dissemination is by wind over an effective range of about 200 feet *(27)*. The maximum spread depends upon the rate of seedfall, (reported to be 3.9 feet per second in still air) *(33)*, height at which seeds are produced, and wind velocity. Seed is also spread to some extent by rodents making cone caches.

VEGETATIVE REPRODUCTION

No reports were found of red spruce having been reproduced either by grafting or by cuttings. Unlike the closely related black spruce, red spruce does not reproduce by layering.

SEEDLING DEVELOPMENT

The germination of commercial lots of seed is reported to range from 45 to 85 percent. In nature most red spruce seed germinates the next spring after dispersal; some, however, may germinate in the fall soon after dropping from the tree *(27)*. On favorable seedbeds the usual spring germination period is from late May to early July. On duff, which is more subject to surface drying than most other seedbed materials, some seed may lose its viability by midsummer *(6)*, and some may show delayed germination well into August.

Adequate moisture is the chief controlling factor for red spruce regeneration. Germination will take place on almost any type of seedbed (mineral soil, rotten wood, or shallow duff) except sod *(19, 26, 27, 29, 37)*. On thicker duff, germination may be relatively poor because of the less favorable moisture conditions. Temperatures within the range of 68° to 86°F. are generally favorable for germination *(36)*. Seeds will not germinate satisfactorily at temperatures below 68° *(29)* and are permanently injured by exposure to temperatures above 92° over a long period *(6)*.

Germination and initial establishment are best under cover. Seedlings can become established under reduced light intensities down to a minimum of 15 or 20 percent of full

Figure 4.--*Cones and seeds of red spruce.*

Figure 5.--*Red spruce seedlings 1, 4, and 8 years old (left to right). Note the shallow root systems.*

noon sunlight *(29)*. Seedlings starting in the open undergo heavy initial mortality as a result of high surface temperatures, drought, and frost heaving *(5, 26, 29)*. However, despite such losses in the open, abandoned agricultural land in northern New England commonly seeds in to pure red spruce or red spruce and other conifers. Few losses occur after the first year and seedlings that survive in the open grow better than those under shade.

Natural reproduction depends more on factors determining seedling survival than on requirements for germination. Spruce seedlings are characterized by an exceptionally slow-growing, fibrous, shallow root system (fig. 5); so a critical factor in their survival and establishment on forest land is the depth of the L and H organic layers of the soil profile. When the combined thickness of these layers exceeds 2 inches, spruce establishment may be severely limited because the seedlings do not reach mineral soil and the moisture necessary to carry them through dry periods *(29)*. In general, the closer to mineral soil the seeds lie at germination time, the greater the establishment of seedlings. Seedlings of red spruce and the commonly associated balsam fir are similar in many respects and controlled by the same factors, but as a rule spruce is the weaker, more fragile, slower-growing species during the establishment period.

Small seedlings are subject to winter mortality from frost-heaving and from smothering or crushing by litter or

snow. Smothering is more prevalent in mixed stands where there is a heavy fall of hardwood leaves.

Once red spruce seedlings are established, their early growth is determined largely by the amount and character of the competition. They must compete in many places with the more prolific and faster-growing balsam fir. However, on lands heavily cut-over, the severest competitors are dense bracken fern, raspberry, and hardwood sprouts--especially maple sprouts *(37)*. Often the young spruces are unable to survive under such competition, and hardwoods take over. In northern New England alone, red spruce has nearly disappeared from more than a million acres of formerly spruce-hardwood forest as a result of heavy cutting of the spruce *(43)*.

Red spruce is one of the last species to start height growth in the spring, usually beginning the first week of June and ending from 9 to 11 weeks later *(4, 10)*. Radial growth usually starts about the second week of June and continues through August *(31)*.

SAPLING STAGE TO MATURITY

Growth and Yield

Red spruce is a medium-size tree at maturity, reaching 12 to 24 inches in diameter and 60 to 75 feet in height in the Northeast, and up to 115 feet in the Appalachian Mountains *(27)*. The largest tree on record is reported from the southern Appalachians; it reached a diameter of 57 inches and a height of 162 feet. The largest known living tree is 54 inches in diameter and 75 feet tall *(1)*. Maximum age is reported to be about 400 years *(9)*.

Red spruce is a shallow-rooted species. Its average rooting depth for all classes of sites in Maine was found to be 13 inches, with a maximum of 22 inches.[1] Because of its shallow rooting, red spruce is subject to windthrow, particularly on thin or wet soils *(22)*.

Rate of growth of red spruce after the establishment period is much influenced by light conditions. Although trees will live and grow slowly in dense shade for many years, they require nearly full light for best development. Understory trees no more than 4 or 5 feet tall may be over 50 years old *(9)*, whereas trees of the same age in the open may be approaching small sawtimber size. A comparison of height growth of trees growing in the forest and in the open is given by Murphy *(27)* as follows:

Age (years)	In forest	In open
	Feet	Feet
5	0.3	0.8
10	.7	2.4
15	1.1	6.0
20	1.5	10.0
25	2.0	16.0
30	2.6	28.0
35	3.3	35.0
40	4.1	--
45	5.0	--

Red spruce under suppression retains for many years the ability to respond to release with a growth rate approaching that of open-grown trees (fig. 6 and 7). However, vigor of response declines somewhat with age. Suppressed trees 2 to 5 feet tall usually grow more rapidly when released than older ones, 10 or more feet tall, that have grown under similar conditions of suppression. Moreover, the taller trees may require a recovery period of about 5 years before showing accelerated growth *(37)*. Many of the

Figure 6.--*Red spruce responds well to release. The long terminals on these seedlings show how much height growth increased after a cutting 2 years earlier.*

associated tree species outgrow red spruce after release. Studies in Canada indicate that reduction of growth to about 1 inch of diameter increment in 25 years, continued for 100 years, represents about the limit of suppression that red spruce can survive *(32)*.

Under favorable conditions, red spruce may reach an average diameter of nearly 4 inches and a height of 24 feet in 20 years, and over 9 inches in diameter and 61 feet in height in 60 years *(7)*. Dominant trees may grow 1 inch in diameter in 6 to 10 years. Trees 6 to 8 inches in diameter left after cutting may grow an average of 1 inch in 6 years *(9)*.

Growth of red spruce is related to vigor, crown ratio (proportion of total tree height in live crown), and to some extent crown class. A study in Maine[2] showed that high-vigor red spruce with a crown ratio of 0.6 or better averaged 1.7 inches of diameter growth in 10 years. Growth rates for smaller crown ratios and less vigorous trees decreased progressively downward to an average of 0.3 inches in 10 years for low-vigor intermediate trees or trees having a crown ratio smaller than 0.4.

Yields per acre in total cubic-foot volumes of all trees above 0.6 inches d.b.h., including stump and top, are given by Meyer *(23)* as follows:

Age (years)	Site Index				
	70	60	50	40	30
20	200	160	120	80	50
30	1,060	860	680	500	280
40	2,850	2,350	1,860	1,350	750
50	5,350	4,430	3,510	2,550	1,400
60	7,240	6,030	4,780	3,490	1,930
70	8,430	7,020	5,590	4,050	2,260
80	9,150	7,610	6,060	4,400	2,450
90	9,580	7,970	6,340	4,600	2,560
100	9,870	8,210	6,520	4,740	2,640
110	10,100	8,410	6,680	4,800	2,700

These yields were calculated by Meyer from sample plots in pure, even-aged spruce-fir stands, mostly on old fields. They tend to exaggerate the yields that might be

[2]McLintock, T. F. A tree classification for red spruce and balsam fir. Unpublished manuscript, Northeastern Forest Experiment Station, 1953.

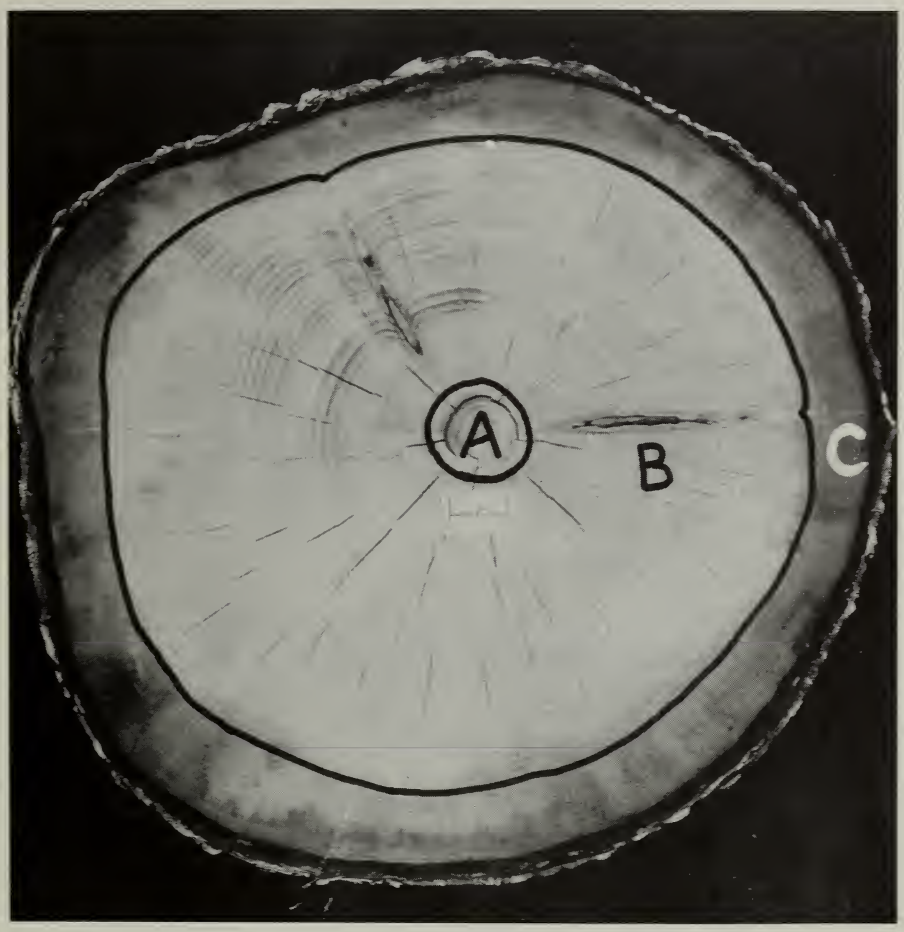

Figure 7.--*This cross-section of a 14-inch stem shows how red spruce responds to release after suppression.*

During 48 years of suppression (A) *the tree grew only 1.7 inches in diameter. After release* (B) *it grew more than 10 inches in 39 years. During the last 21 years* (C) *its growth slowed again to a rate of about 1 inch in 10 years.*

expected from irregular stands such as develop after cutting. Empirical yield tables prepared later for the Northeast by Westveld *(40)* take into consideration stand density, composition, and time since cutting. His tables give merchantable volume of spruce and fir combined in trees 6 inches d.b.h. and up from a 1-foot stump to a 3-inch top diameter inside bark.

The following tabulation from Westveld shows, for different stand densities and different ages since cutting,

the yields in cubic feet of merchantable volume in stands on dominant softwood sites where 90 percent or more of the trees are spruce and fir:

Age since cutting (years)	Density index (Regional average = 100)		
	50	100	150
10	245	349	422
20	425	539	618
30	622	743	828
40	830	961	1,049
50	1,054	1,187	1,281

Reaction to Competition

Red spruce is classified as tolerant in New York and New England and very tolerant to tolerant in Canada *(3, 12)*. Some authors rate it more tolerant and others consider it less tolerant than balsam fir. However, the relative tolerance may vary with soil fertility and climate *(29)*.

Its chief competition comes from balsam fir and the heavy-shade-producing hardwoods like beech and maple. Competition from aspen, birch, and other thin-crowned species is not so severe. Red spruce prunes itself well in dense stands.

Red spruce is considered a climax species in the Appalachian Mountains and in Algonquin Park, Ontario, and subclimax throughout the rest of its range *(12)*.

Susceptibility to Injury

Because of its shallow root system, thin bark, and characteristic resinous exudations, red spruce trees of all ages and sizes are easily killed by fire. The estimated 1½-million acres of red spruce originally growing in the southern Appalachians have been reduced to scattered fringes and small isolated patches through clear-cutting followed by fire *(24)*.

Red spruce has several insect enemies *(11)*. The most important is the spruce budworm (*Choristoneura fumiferana*), which is most likely to cause heavy damage to spruce in stands that contain a high proportion of balsam fir. Widespread outbreaks have caused severe damage in Maine and eastern Canada. Mature and overmature stands of red spruce

are also subject to severe damage by the eastern spruce beetle (*Dendroctonus piceaperda*). Two species of sawflies, the introduced European spruce sawfly (*Gilpinia hercyniae*) and the native yellow-headed spruce sawfly (*Pikonema alaskinses*), have caused severe defoliation of red spruce in localized areas.

Red spruce has few diseases. However, needle cast caused by *Lophodermium filiforme* may at times cause severe defoliation of the lower crowns and a subsequent reduction of increment *(8)*.

Fomes pini and *Polyporus schweinitzii*, the most destructive of red spruce wood-rotting fungi, are usually confined to overmature or damaged trees. *Polyporus borealis* has been found causing a butt rot in overmature trees *(25)*. The incidence of decay appears to be definitely related to the age of the tree but is not affected by site or rate of growth.

Special Features

Spruce gum, the exudate that accumulates on trunk wounds of red spruce, was the raw material for a flourishing chewing-gum industry in Maine during the last half of the 19th century and early years of this century. But because of high labor costs of procuring gum, and loss of the market to the chicle chewing-gum manufacturers, "State of Maine Pure Spruce Gum" is now rarely seen in drug stores.

In one quality, the wood of red spruce has peerless excellence: its resonance. So for piano sounding boards, guitars, mandolins, organ pipes, and violin bellies, red spruce is the preferred wood. Some violin makers say there is no substitute for it.

For such uses, the wood preferred must have narrow and uniform growth rings, and must be straight-grained and knot-free. The red spruce, with its even structure, absence of vessels, fine and regularly distributed medullary rays, and long straight fibers, produces just such a wood.

Races and Hybrids

No geographic races of this tree have been reported. Two successful species crosses involving red spruce have been made: *Picea abies* (female) x *P. rubens*, and *P. rubens* (female) x *P. mariana (18, 43)*.

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